

We claim:

1. A photomask assembly comprising a photomask substrate, a porous frame, and a pellicle, wherein the porous frame has a gas permeability to oxygen or nitrogen higher than about $10 \text{ ml.mm/cm}^2\text{.min.MPa}$, an average pore size between 0.001 micrometer and 10 micrometers, and a coefficient of thermal expansion between $0.01 \text{ ppm/}^\circ\text{C}$ and $10 \text{ ppm/}^\circ\text{C}$.
2. A photomask assembly as defined in claim 1, wherein the porous frame has a gas permeability to oxygen or nitrogen higher than about $40 \text{ ml.mm/cm}^2\text{.min.MPa}$.
3. A photomask assembly as defined in claim 1, wherein the porous frame has a gas permeability to oxygen or nitrogen higher than about $70 \text{ ml.mm/cm}^2\text{.min.MPa}$.
4. A photomask assembly as defined in claim 1, wherein the porous frame has an average pore size between 0.01 micrometer and 1 micrometer.
5. A photomask assembly as defined in claim 1, wherein the porous frame has an average pore size between 0.08 micrometer and 1 micrometer.
6. A photomask assembly as defined in claim 1, wherein the porous frame has a coefficient of thermal expansion between $0.1 \text{ ppm/}^\circ\text{C}$ and $1 \text{ ppm/}^\circ\text{C}$.
7. A photomask assembly as defined in claim 1, wherein the porous frame has a coefficient of thermal expansion between $0.3 \text{ ppm/}^\circ\text{C}$ and $0.7 \text{ ppm/}^\circ\text{C}$.
8. A photomask assembly as defined in claim 1, wherein the porous frame is attached to a photomask substrate and/or a hard pellicle, and wherein the porous frame has a coefficient of thermal expansion that matches that of the photomask substrate and/or the hard pellicle within $\pm 20\%$.
9. A photomask assembly as defined in claim 1, wherein the porous frame has surface flatness less than about 20 micrometers.

10. A photomask assembly as defined in claim 1, wherein the porous frame has a surface flatness less than about 5 micrometers.
11. A photomask assembly as defined in claim 1, wherein the porous frame has a surface flatness less than about 1 micrometer.
12. A photomask assembly as defined in claim 1, wherein the porous frame has a pore surface area larger than $10 \text{ m}^2/\text{g}$.
13. A photomask assembly as defined in claim 1, wherein the porous frame has a pore surface area larger than $25 \text{ m}^2/\text{g}$.
14. A photomask assembly as defined in claim 1, wherein the porous frame has a pore surface area larger than $70 \text{ m}^2/\text{g}$.
15. A photomask assembly as defined in claim 1, wherein the porous frame has an elastic modulus higher than 1 GPa.
16. A photomask assembly as defined in claim 1, wherein the porous frame has an elastic modulus higher than 5 GPa.
17. A photomask assembly as defined in claim 1, wherein the porous frame has an elastic modulus higher than 10 GPa.
18. A photomask assembly as defined in claim 1, wherein the porous frame has a modulus of rupture higher than 1 MPa.
19. A photomask assembly as defined in claim 1, wherein the porous frame has a modulus of rupture higher than 5 MPa.
20. A photomask assembly as defined in claim 1, wherein the porous frame has a modulus of rupture higher than 10 MPa.
21. A photomask assembly as defined in claim 1, wherein the porous frame is configured to scavenge certain chemicals in an amount higher than 0.01 weight percent of the material of the porous frame.

22. A photomask assembly as defined in claim 1, wherein the porous frame is configured to scavenge certain chemicals in an amount higher than 0.05 weight percent of the material of the porous frame.

23. A photomask assembly as defined in claim 1, wherein the porous frame is formed of a material selected from the group consisting of silica, fluorinated silica, ZrO_2 , Al_2O_3 , $\text{SiO}_2 - \text{Al}_2\text{O}_3$, $\text{SiO}_2 - \text{B}_2\text{O}_3$, and mixtures thereof.

24. A photomask assembly as defined in claim 1, wherein the porous frame is formed of a material selected from the group consisting of silica and fluorinated silica having a purity of greater than about 96 weight percent silica.

25. A method for making a photomask assembly, comprising:
providing a photomask substrate, a porous frame, and a pellicle, wherein the porous frame has a gas permeability to oxygen or nitrogen higher than about 10 ml.mm/cm².min.MPa, an average pore size between 0.001 micrometer and 10 micrometers, and a coefficient of thermal expansion between 0.01 ppm/°C and 10 ppm/°C; and

attaching together the photomask substrate, the porous frame, and the pellicle, to form a photomask assembly.

26. A method as defined in claim 25, wherein providing a porous frame comprises: (a) preparing a gel by a sol-gel process, (b) drying the gel, and (c) partially densifying the dry gel.

27. A method as defined in claim 26, and further comprising machining the densified dry gel to form the porous frame.

28. A method as defined in claim 26, and further comprising machining the densified dry gel to form rectangular bars and welding the bars to form the porous frame.

29. A method as defined in claim 26, and further comprising machining the densified dry gel using a process selected from the group consisting of diamond tool machining, ultrasonic milling, laser machining, and water jet machining.

30. A method as defined in claim 26, and further comprising machining the densified dry gel using a process selected from the group consisting of diamond tool machining and ultrasonic milling.

31. A method as defined in claim 26, wherein preparing a gel comprises shaping the gel in a mold having dimensions such that when the gel is subsequently dried and partially densified, the frame will be configured to have desired dimensions without the need for machining.

32. A method as defined in claim 26, and further comprising machining the densified dry gel to less than 20-micrometer surface flatness.

33. A method as defined in claim 26, wherein the dry gel comprises silica.

34. A method as defined in claim 26, wherein the gel comprises silicon alkoxide and fumed silica.

35. A method as defined in claim 26, wherein partially densifying comprises partially densifying the dry gel at a prescribed partial densification temperature in an atmosphere comprising helium, nitrogen, oxygen, or mixtures thereof.

36. A method as defined in claim 35, wherein partially densifying occurs at a partial densification temperature within a range of 650 °C to 1260 °C.

37. A method as defined in claim 35, wherein partially densifying occurs at a partial densification temperature within a range of 1100 °C to 1200 °C.

38. A method as defined in claim 35, wherein partially densifying occurs at a partial densification temperature of about 1180 °C.

39. A method as defined in claim 35, wherein partially densifying comprises heating the dry gel to the prescribed partial densification temperature at a rate between 1 °C/hr and 200 °C/hr.

40. A method as defined in claim 35, wherein partially densifying comprises heating the dry gel to the prescribed partial densification temperature at a rate between 10 °C/hr and 100 °C/hr.

41. A method as defined in claim 35, wherein partially densifying comprises heating the dry gel to the prescribed partial densification temperature at a rate of about 15 °C/hr.

42. A method as defined in claim 35, wherein partially densifying comprises maintaining the dry gel at the prescribed partial densification temperature for a duration in a range of 1 hour to 100 hours.

43. A method as defined in claim 35, wherein partially densifying comprises maintaining the dry gel at the prescribed partial densification temperature for a duration in a range of 1 hour to 30 hours.

44. A method as defined in claim 35, wherein partially densifying comprises maintaining the dry gel at the prescribed partial densification temperature for a duration of about 4 hours.

45. A method as defined in claim 35, wherein the atmosphere consists essentially of a mixture of oxygen and nitrogen or helium, the mixture having an oxygen concentration between 3 % and 20 %.

46. A method as defined in claim 35, wherein the atmosphere consists essentially of a mixture of oxygen and nitrogen or helium, the mixture having an oxygen concentration of about 7 %.

47. A method as defined in claim 26, and further comprising removing hydrocarbons from the dry gel by heating the dry gel at a temperature between 150 °C and 300 °C.

48. A method as defined in claim 47, and further comprising halogenating the dry gel using a halogenation agent at a temperature between 650 °C and 1,200 °C, after the step of removing hydrocarbons.

49. A method as defined in claim 48, and further comprising: (a) oxygenating the dry gel after the step of halogenating, and (b) re-halogenating the dry gel after the step of oxygenating.

50. A method as defined in claim 26, wherein the step of partially densifying the dry gel further comprises:

partially densifying the dry gel at a prescribed initial partial densification temperature;

machining the partially densified dry gel to a desired porous frame shape; and

partially densifying the porous frame at a prescribed final partial densification temperature, wherein the final partial densification temperature is greater than the initial partial densification temperature by between about 50 °C and about 300 °C.

51. A method as defined in claim 50, wherein the prescribed final partial densification temperature is in a range of 650 °C and 1,260 °C.

52. A method as defined in claim 50, wherein the prescribed final partial densification temperature is in a range of 1,100 °C and 1,200 °C.

53. A method as defined in claim 50, wherein the prescribed final partial densification temperature is about 1,180 °C.

54. A method as defined in claim 50, wherein partially densifying the dry gel comprises:

partially densifying the dry gel at the prescribed initial partial densification temperature;

machining the partially densified dry gel after the step of partially densifying the dry gel, to produce a desired porous frame shape;

annealing the machined dry gel, at an annealing temperature that ranges between the initial partial densification temperature and about 300 °C lower than the initial partial densification temperature; and

partially densifying the annealed dry gel at a prescribed final partial densification temperature, wherein the final partial densification temperature is higher

than the initial partial densification temperature by between about 50 °C and about 300 °C.

55. A method of making a porous silica frame suitable for use in a photomask assembly, comprising:

preparing a dry gel comprising more than 99.9 % silica, using a sol-gel method;

halogenating the dry gel by heating the dry gel from about 650 °C to about 1,050 °C, at a heating rate of about 25 °C/hr in an atmosphere of about 33 % chlorine and about 67 % helium, and maintaining the dry gel at about 1,050 °C, for a duration of about 1 hour in the atmosphere;

partially densifying the halogenated dry gel by heating the halogenated dry gel from about 1,050 °C to about 1,180 °C, at a heating rate of about 25 °C/hr in an atmosphere of about 7 % oxygen and about 93% helium, and maintaining the halogenated dry gel at about 1,180 °C for about 4 hours; and

machining the partially densified dry gel into a desired frame shape having a flatness of less than 1 micrometer.